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Early Silurian sea-level changes in southern Turkey: Lower Telychian conodont data from the Kemer area, western Taurides

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Abstract – A rich conodont fauna of the *Pterospathodus eopennatus* Zone (lower Telychian), the oldest Silurian fauna from the southern Taurides, was recovered from the middle Sapandere Formation of the upper Antalya Nappe at Kemer, western Taurides, Turkey. It is similar to European warm-water conodont faunas of the same age. This suggests the formation was initiated by a pre-Telychian (?Aeronian) transgression. The Ashgill of the same area contains Perigondwana cold-water fossils, whereas early Llandovery glacio-marine deposits to the southeast contain exotic dropstones, such as micaschists and orthogneisses. The warming after the end Ordovician-earliest Silurian glaciation caused a rapid global sea-level rise resulting in deposition of black shales during the Aeronian, followed by a drop in sea-level in the late Telychian of southern Turkey.

INTRODUCTION

Age data for Early Palaeozoic rocks in Turkey are very limited. They have received less attention than either Late Palaeozoic or Mesozoic strata. This is especially the case for Early Silurian sediments that constitute important hydrocarbon source units. The Late Ordovician-Early Silurian period in Perigondwana was marked by rapid global sea-level fluctuations as indicated by unconformities and transgressions. It is commonly accepted that these features result from waxing and waning of ice-sheets in northwest Gondwana (Scotese and McKerrow 1990) but may, in some cases, be related to local tectonic events.

It is also established that the onset of the Silurian was characterised by a regional transgression in northwest Gondwana (Holland 1981 and the references therein). The most distinctive Early Silurian deposits in this area are organic-rich, cold-water siliciclastics (black shales) associated with the melting of the South Polar ice-cap. These black shales can be traced laterally for hundreds of kilometres (Rutherford *et al.* 1997). They are regionally underlain by clastics that contain diamictites (dropstones – heterometric sandstones) and overlain by shallow-water clastic-carbonate successions in Arabia, Iran and southern Turkey.

In this paper we report biostratigraphical data on poorly known Silurian sediments in the Kemer Unit of the Upper Nappe by re-examining earlier conodont data (Göncüoglu unpublished data), the first Early Silurian conodont data from the western Taurides. We aim to establish a more reliable stratigraphical framework for the Early Palaeozoic sequence in the Antalya nappes in the western Taurides and correlate this data with information from the Central and Eastern Taurides, and the Eastern Mediterranean region to develop a better understanding of the global sea-level changes during the Early Silurian and their possible causes.

REGIONAL GEOLOGICAL FRAMEWORK

The very complex structure in the western Bey Daglari area to the northwest of the Antalya Bay (Figure 1) consisting of numerous tectonic slivers of Palaeozoic and Mesozoic platform sequences, volcanic assemblages and ophiolitic rocks has been noted in the earliest geological studies (e.g. Tietze 1885). Altinli (1944) was the first to recognise the presence of an autochthonous sequence (Bey Daglari Anticline) flanked on both sides by allochthonous nappes; these were later named the Lycian nappes (Brunn *et al.* 1970) in the west and the Antalya nappes (Lefevre 1967) in the east. Altinli (op. cit) revealed that detailed biostratigraphical studies were required to separate the tectonic units because of lithostratigraphical similarities. Marcoux (1970, 1977, 1979) mapped the area to the west of the Antalya Bay, and subdivided the allochthonous Antalya nappes into the Early-, Middle-and Upper Nappe. Each of these were further subdivided into tectonic units.

Palaeozoic sequences are the main constituents of the Upper Nappe, constituting the Bakirlidag, Kemer and Tahtalidag units (Marcoux 1970). In the Bakirlidag Unit the sequence starts with neritic Permian carbonates followed by Scythian marls,

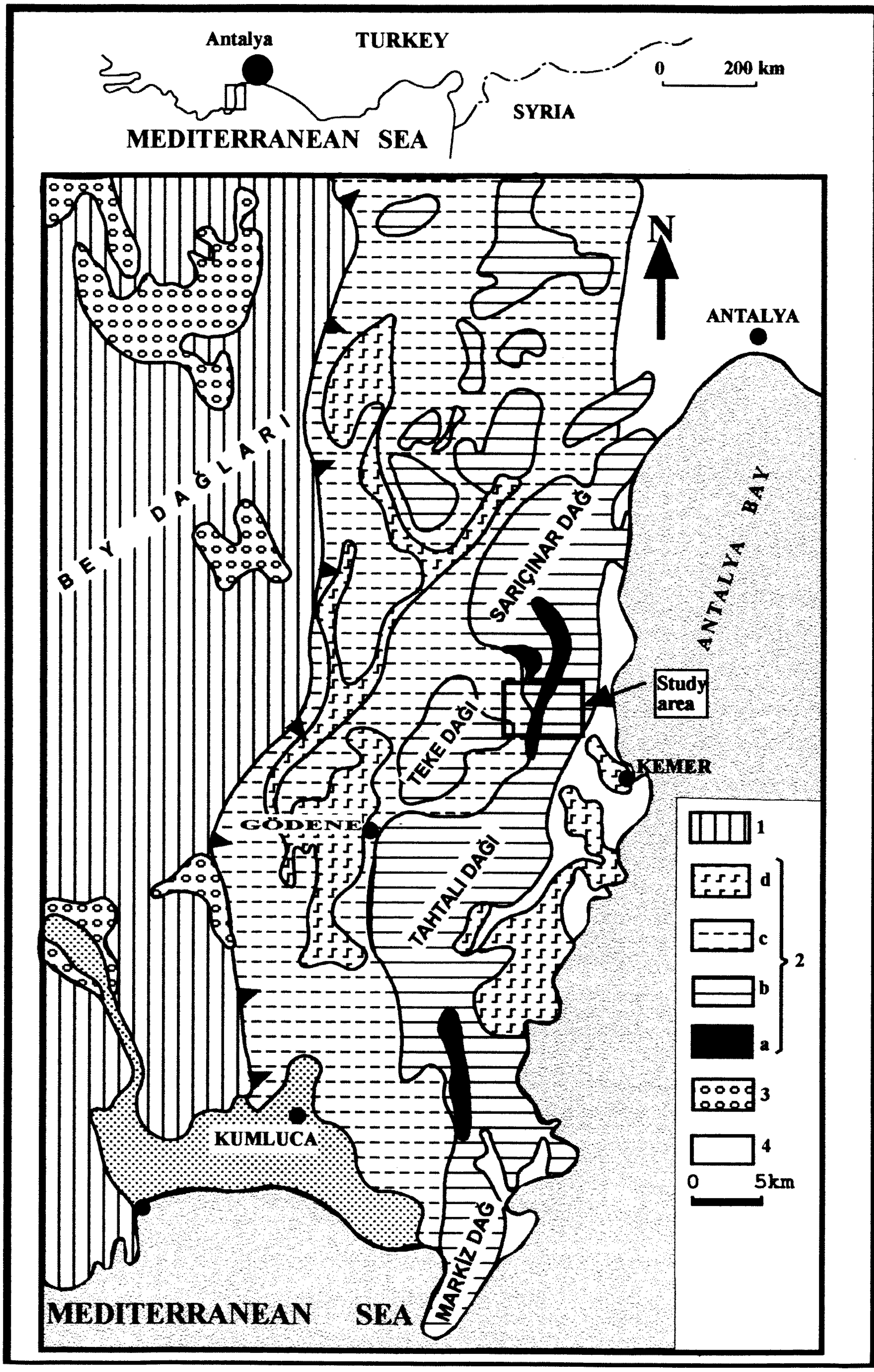

Figure 1 Location and structural map of the western Antalya Bay showing the main tectonic units (modified from Senel 1986). 1- Bey Daglari Autochthon, 2-Antalya nappes, a) Palaeozoic units, b) Mesozoic-Early Tertiary platform sequences, c) Late Cretaceous melange, d) Ophiolites, 3- Tertiary (Eocene-Miocene) cover, 4- Alluvium.

Anisian-Norian pelagic limestones and Upper Norian-Cretaceous platform carbonates, respectively, and thus differs from the other units because of an absence of Early Palaeozoic sequences. The Kemer Unit, by comparison consists of Ordovician-Permian sediments overlain by Scythian marls, Ladinian bedded cherts and Late Triassic-Cretaceous pelagic limestones (Şenel 1986). Recent work (Şenel *et al.* 1992) has shown that the Palaeozoic succession commences with Middle Cambrian carbonates. The Kemer Unit has a more complete Palaeozoic succession as well as differences in the Mesozoic sequence of other units. In the third unit of the Upper Antalya Nappe, (Tahtalidag Subunit: Marcoux 1979; Tahtali Unit: Şenel 1986) Jurassic-Cretaceous neritic carbonates unconformably cover the so-called "Ordovician shales", the distinguishing feature being the absence of the Early Silurian and Middle Palaeozoic-Triassic sequences (Marcoux 1977, 1979; Şenel *et al.*1983; Şenel 1986). Şenel *et al.* (1992) used the name Tahtalidag Nappe as a synonym of the Upper Antalya Nappe; this is not to be confused with the Tahtalidag Unit of Marcoux (1977) or Tahtali Unit of Şenel (1986).

As this brief review shows, all the tectonic units in the area have been distinguished by differences in depositional features of contemporaneous sediments, or through comparisons between Palaeozoic and Mesozoic sequences within the units. These sequences, however, have lithostratigraphic similarities. Moreover, the presence of numerous structural discontinuities precludes stratigraphical order as a reliable tool in isolation. Detailed biostratigraphical work on the sedimentary successions is therefore required.

STRUCTURAL SETTING AND STRATIGRAPHY OF THE SILURIAN SEDIMENTS IN THE KEMER UNIT

The Kemer Unit is the middle thrust-slice of the Upper Antalya Nappe. It crops out as a N-S trending tectonic sliver, almost 10 km long, to the WNW of Kemer.

The succession of the Palaeozoic units is well exposed along the Kesmebogazi, Belen Dere and Sapan Dere gorges. These locations show the typical sequence of Palaeozoic sediments in the Kemer Unit of the western Antalya nappes. The lower contact of the Palaeozoic succession in Belen Dere is a steep thrust-plane along which the lowermost unit, the Sariyardere Formation, is thrust over Early Triassic marls.

The Silurian sediments in the type-area were first described by Marcoux (1977, 1983) and later named as Sapandere Formation by Şenel *et al.* (1983). The lithology is characterised by an alternation of thick-bedded sandstones, sandy dolomites, and subordinate sandy limestones and shales (Figures 2 and 3). In the type section, to the southeast of Sapan Dere, the formation starts with gray-brown, thick-bedded sandstones, followed by sandstones with well-developed cross-bedding and symmetric

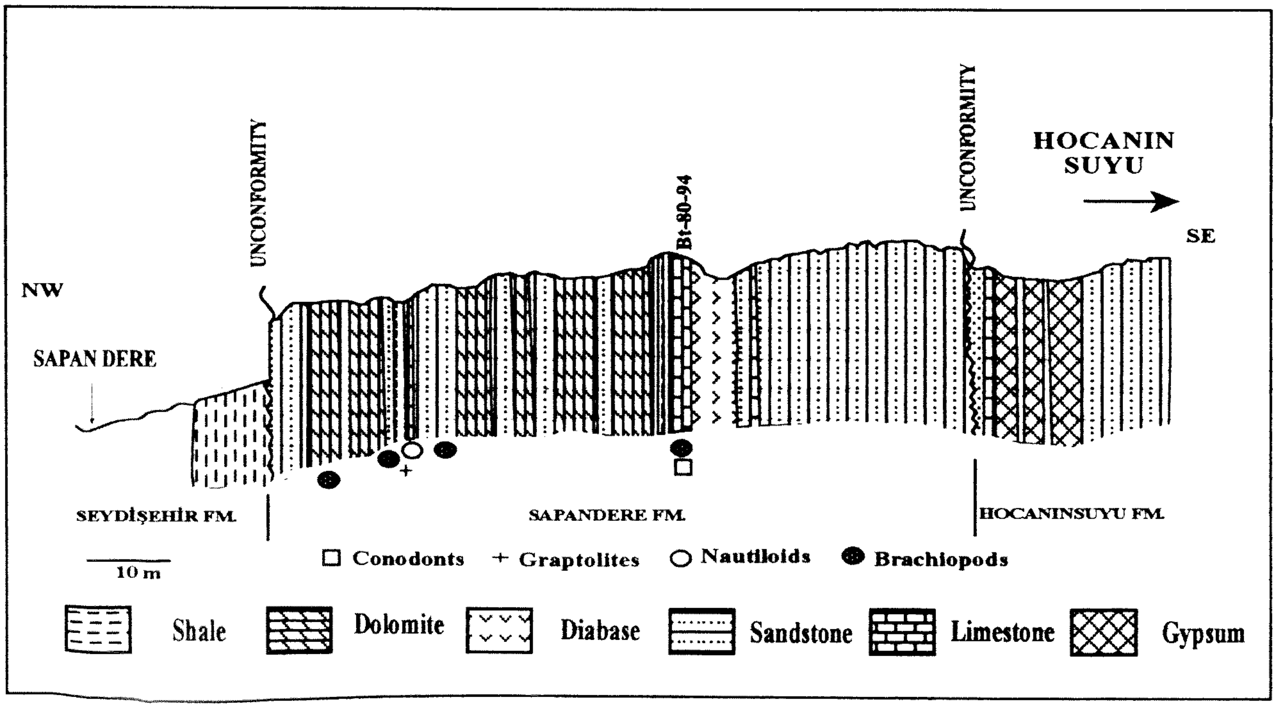

Figure 2 Cross-section showing the contact relations and rock units of the Sapandere Formation in its type locality (after Şenel 1986).

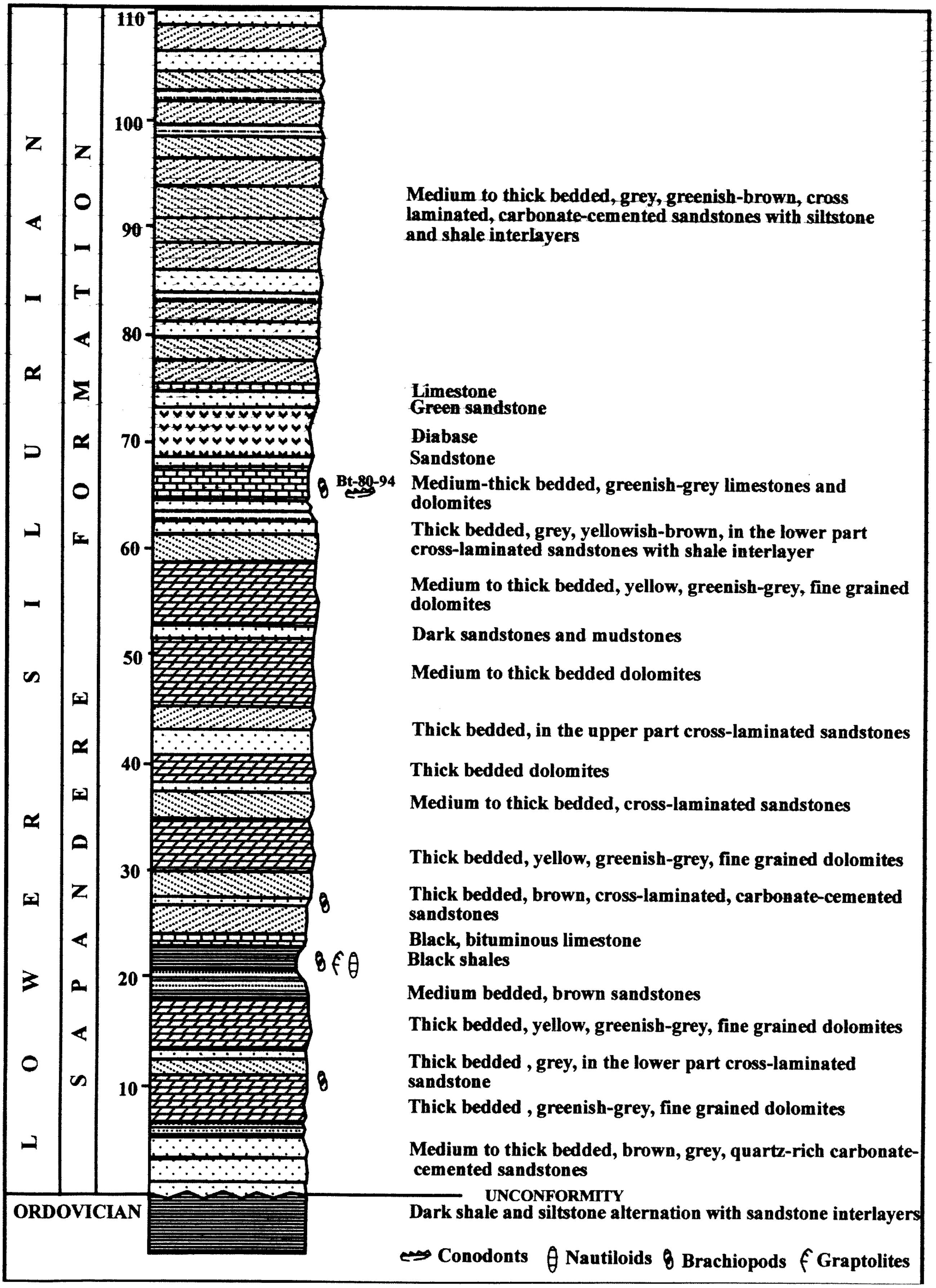

Figure 3 Section of the Sapandere Formation measured at its type locality (after Şenel 1986).

1	2	Stage	Graptolite Zone	Conodont Zone
SILURIAN	Pridoli		bouceki-transgrediens	Ozarkodina eosteinhornensis-Oulodus elegans detortus
			branikensis-lochkovensis	Ozarkodina remscheidensis Interval Zone
			parultimus-ultimus	
	Ludlow	Ludfordian	formosus	Ozarkodina crispa; Ozarkodina snajderi
			bohemicus tenuis-kozlowskii	Pedavis latialatus
			leintwardinensis	Polygnathoides siluricus; Ancoradella ploeckensis
		Gorstian	scanicus	Ozarkodina excavata hamata
			nilssoni	Kockelella v. variabilis; Polygnathoides crassus
	Wenlock	Homerian	ludensis	Ozarkodina bohemica
			praedeubeli-deubeli	
			parvus-nassa	
			lundgreni	Ozarkodina sagitta sagitta
		Sheinwoodian	rigidus-perneri	Ozarkodina sagitta rhenana
			riccartonensis-belophorus	Kockelella ranuliformis
			centrifugus-murchisoni	
	Llandovery	Telychian	lapworthi	Pterospathodus amorphognathoides
			spiralis Interval Zone	
			crenulata	Pterospathodus celloni
			griestoniensis	
			crispus	Pterospathodus eopennatus
			turriculatus	
			guerichi	Pterospathodus tenuis-Distomodus staurognathoides
		Aeronian	sedgwickii	
			convolutus	
			leptotheca	
			magnus	
			triangulatus	
		Rhuddanian	cyphus	Distomodus kentuckyensis
			acinaces	
			atavus	
			acuminatus	Ozarkodina ? nathani

Table 1 Silurian graptolite and conodont zonations. Revised after "The Subcommission on Silurian Stratigraphy" (1995). Vertical distances not time-related. 1: System. 2. Series.

ripple-marks alternating with greenish to yellowish-gray thick bedded dolomites (Figure 3). The first black shale, 20 m above the base, contains abundant graptolites *(Monograptus* sp. indet.), pyritized nautiloids and brachiopods in carbonate-bearing layers. These have not been studied in detail. Above this there is a thick package of sandstone, alternating sandy dolomite and dolomite, with a black sandstone-mudstone layer 53 m above the base.

Conodonts were recovered at 65 m above the base (BT-80-94) from medium bedded, greenish-gray dolomitic limestones (Figure 3). A diabase sill, almost 7 m wide, has caused contact metamorphism in underlying carbonates. The upper part of the Sapandere Formation in its type locality consists of medium to thick-bedded sandstones with low-angle cross-stratification and ripple-marks.

About one km to the southwest of the type-locality, the alternation of dark shales and green quartz-arenites with some nautiloid-bearing sandy limestone lenses corresponds to the lower 18–23 m of type section of the Sapandere Formation (H. Kozur, oral communication) and contains Aeronian conodonts (Göncüoglu *et al.*, in prep). The upper part of this sequence consists of dolomites and sandstones. The Telychian greenish-grey limestones and dolomitic limestones of the type section are not present at this locality.

The Sapandere Formation is underlain by a sharp contact with the Sariyardere Formation (Şenel *et al.* 1983). This mainly consists of an alternation of brown, greenish-black and gray sandstones, siltstones and shales. Its type locality, in the Sariyar Dere, is almost 12 km south of Sapan Dere. The type section of the Sariyardere Formation is characterised by well developed cone-in-cone structures and diabase sills and dykes. Marcoux (1983) assigned the upper part of the type section of the Sariyardere Formation to the Sort Tepe Formation, established by Dean *et al.* (1981, in Dean and Monod 1990) and he reported casts of brachiopods together with *Piacoporia* that suggested a Late Ordovician (Ashgill) age for the unit. No Silurian rocks been reported in contact with the Sariyardere Formation at this locality. Şenel *et al.* (1983) and Şenel (1986) correlated the very similar clastic rocks underlying the Sapandere Formation in the Kesmebogazi and Sapan Dere sections with the Sariyardere Formation, but noted the absence of diabase dykes in the latter locality. Şenel *et al.* (1983) and Şenel (1986) suggested a conformable contact between these two units and a Late Ordovician age for the clastics based on this correlation. We believe, however, that the previously identified Sariyardere Formation at these localities belong to the Early Ordovician upper Seydişehir Formation, and therefore do not use the term Sariyardere Formation in this context.

The Sapandere Formation is unconformably overlain by the Middle-Late Devonian Hocaninsuyu Formation. The unconformity is accentuated by truncation of the underlying layers and oxidation on the unconformity surface (Şenel 1986). Significantly, an evaporite -bearing Devonian sequence is only encountered in this area.

CORRELATION WITH OTHER UNITS

To date Early Silurian units are described from only a few localities in the western Taurides (Tahtali Unit: Şenel *et al.* 1983), central Taurides (Akseki-Murtiçi: Demirtaşli *et al.* 1977) and eastern Taurides (Saimbeyli-Tufanbeyli area, Dean and Monod 1990).

Demirtaşli (1984) distinguished the Egripinar and Hirmanli formations in the Akseki-Murtiçi area, part of the Geyikdag Autochthon. The Egripinar Formation consists of a lower thick-bedded, yellow to buff arkosic sandstone and conglomerate sequence overlain by a turbiditic sandstone-siltstone member yielding an Early Silurian miospore association. The conformably overlying Hirmanli Formation primarily consists of very thin-bedded, pyrite-bearing siliceous black shales alternating with very fine laminated black shales with Early Silurian graptolites *(Monograptus* cf. *M. spiralis* Geinitz, *Monograptus* cf. *M. aculus* Lapworth, *Climacograptus* cf. *C. scalaris* Risinger, *Rastrites* sp.). It is assumed these very fine laminated shales were deposited in a deep, restricted basin (Demirtaşli 1984).

In the eastern Taurides (Saimbeyli-Tufanbeyli area), the equivalents of the Sapandere Formation were subdivided by Özgül *et al.* (1973) into three formations. The lower part (Halityayla Formation) consists of sandstones and conglomerates interlayered with heterometric sandstones of probable glacio-marine origin. They are overlain by late Aeronian black shales, the Puscutepe Shale Formation (Dean and Monod 1990). The uppermost formation (Yukariyayla Formation) consists of lower limestones and upper turbiditic clastics. The lower limestone bands are rich in nautiloids. Dean and Monod (1990) suggested a late Aeronian age for these limestones, whereas Göncüoglu and Kozur (in press) report latest Telychian to earliest Wenlock conodonts from these beds.

CONODONT DATA

One conodont sample of the Sapandere Formation (Bt-80-94, location and sampling point in the section are indicated in Figures 1 and 3) from the Sapan Dere section (type section of the Sapandere Formation) yielded a rich and well preserved conodont fauna (CAI = 1-2.5). More than 100 specimens were recovered. The insoluble residues

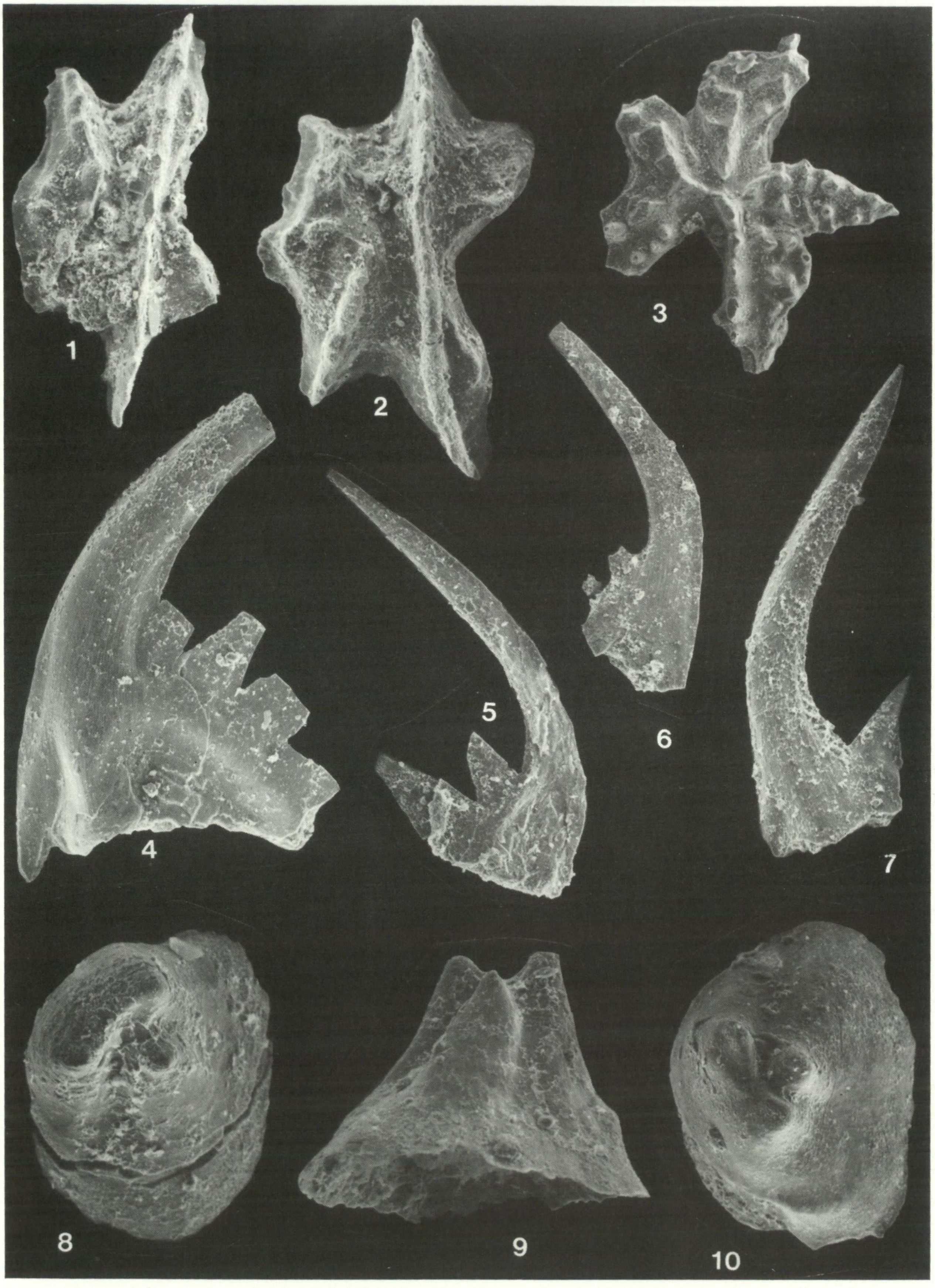

Figure 4 All illustrations are from sample Bt-80-94.**1**, **2**, *Apsidognathus* sp. of the A. *tuberculatus* Walliser group, Pa element, upper view. **1**, x 140, rep.-no. 27-11/1-25. **2**, x 150, rep.-no. 27-11/1-3. **3-7**, *Distomodus staurognathoides* (Walliser). **3**, Pa element, upper view, x80. rep.-no. 27-11/1-1; Sc element. **4**: x 150, rep.-no. 27-11/1-16. **5**, x 150, rep.-no. 27-11/1-24. **6**, x 110, rep.-no. 27-11/1-14. **7**, x 150, rep.-no. 27-11/1-23. **8-10**: *Pseudooneotodus tricornis* Drygant; Fig **8**: upper view, x250, rep.-no. 27-11/1-7. **9**, lateral view, x 250, rep.-no. 27-11/1-10. **10**, upper view, x 150, rep.-no. 27-11/1-6.

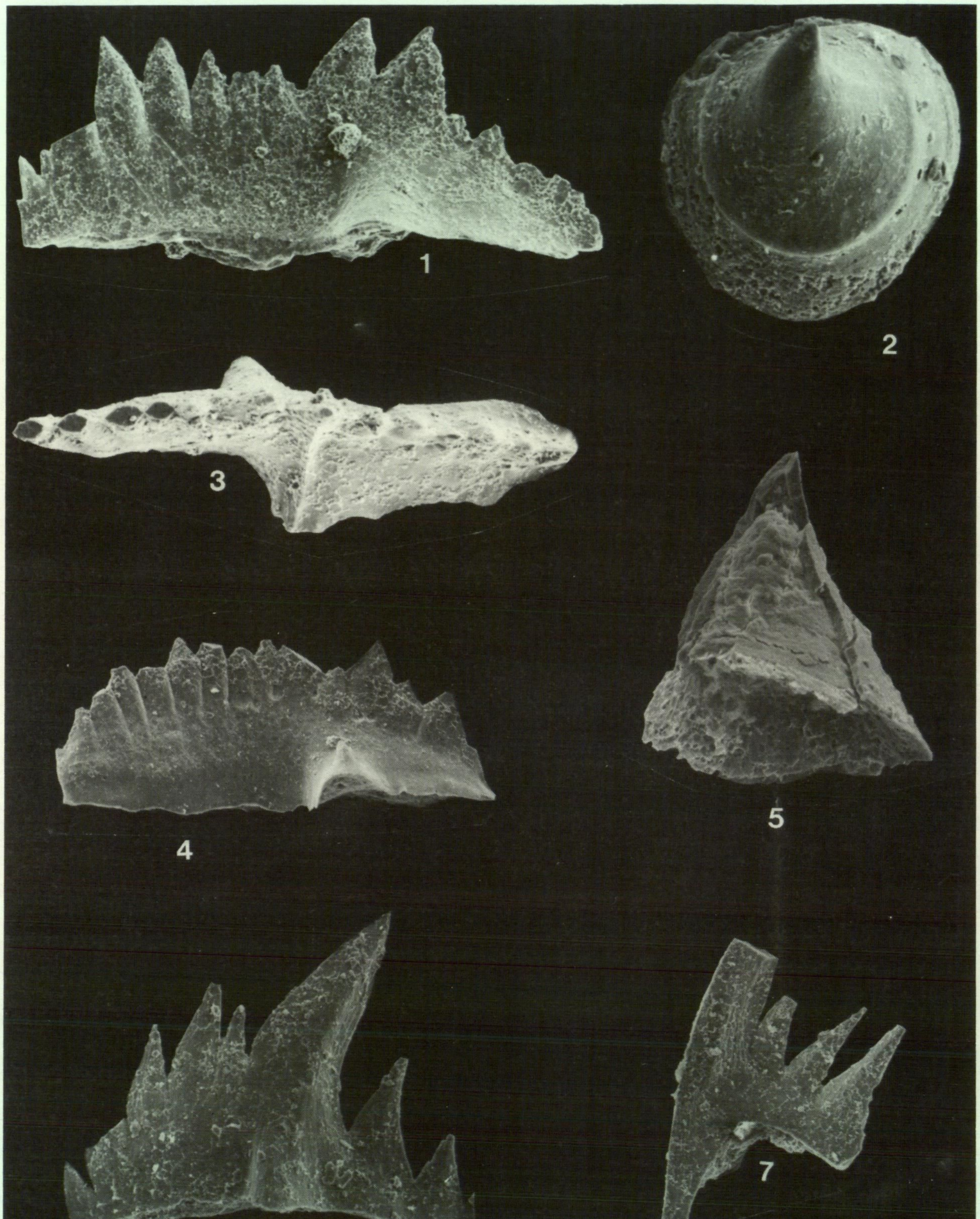

Figure 5 All illustrations are from sample Bt-80-94. **1, 3, 4, 6, 7**, *Pterospathodus eopennatus* Männik. **1**, Pa element, lateral view, x 140, rep.-no. 27-11/1-5. **3**, Pa element, upper view, x 150, rep.-no. 27-11/1-4. **4**, Pa element, lateral view, x 120, rep.-no. 27-11/1-2. **6**, Pb1 element, x 200, rep.-no. 27-11/1-18. **7**, Sc element, x 150, rep.-no. 27-11/1-17. **2, 5**, *Pseudooneotodus beckmanni* (Bischoff and Sannemann). **2**, upper view, x 300, rep.-no. 27-11/1-8. **5**, lateral view, x 250, rep.-no. 27-11/1-9.

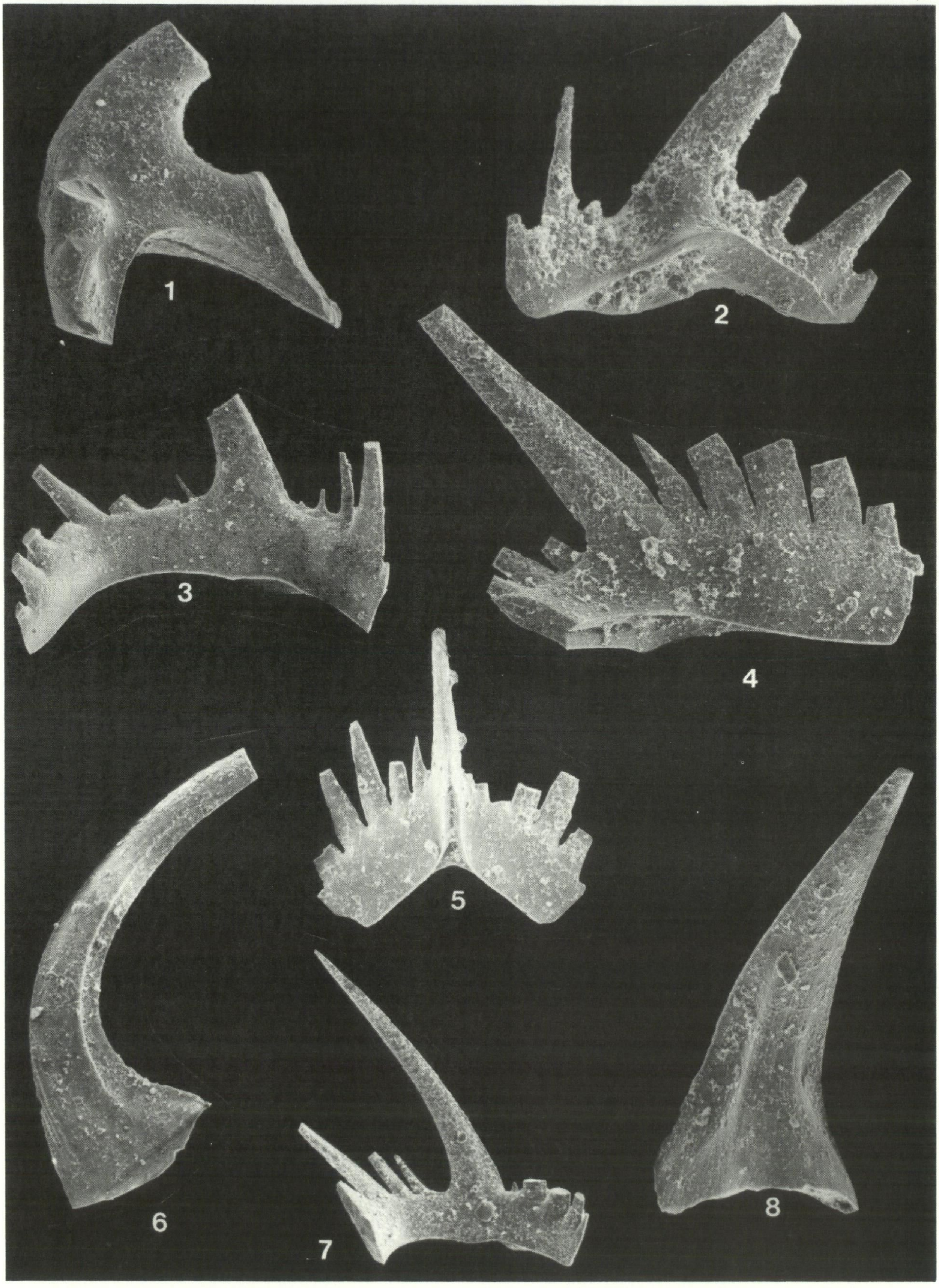

Figure 6 All illustrations are from sample Bt-80-94.**1, 2**, *Oulodus* n. sp. A *sensu* Over and Chatterton 1987, x 140. **1**, Sc element, rep.-no. 27-11/1-11. **2**, ?Pa element, rep.-no. 27-11/1-19. **3-5, 7**, *Oulodus fluegeli* (Walliser). **3**, Sc element, x 150, rep.-no. 27-11/1-21. 4: Pb element, x 200, rep.-no. 27-11/1-22. **5**, Sa element, x 150, rep.-no. 27-11/1-15. **7**, Sc element, x 80, rep.-no. 27-11/1-20. **6**, *Decoriconus* cf. *fragilis* (Branson and Mehl), x 200, rep.-no. 27-11/1-12. **8**, *Dapsilodus* sp., x 120, rep.-no. 27-11/1-38.

also include some foraminifers, ostracodes and brachiopods. All conodonts illustrated on Figures 4–6 are from sample Bt-80-94, *Pterospathodus eopennatus* Zone of lower Telychian (lower part of upper Llandovery), middle Sapandere Formation from the Sapan Dere section, NW of Kemer, Upper Antalya Nappe, western Taurides, southern Turkey.

The following species were determined (Figures 4–6): *Apsidognathus* sp. of the *A. tuberculatus* Walliser group, *Dapsilodus* sp., *Decoriconus* cf. *fragilis* (Branson and Mehl), *Distomodus staurognathoides* (Walliser), *Oulodus fluegeli* (Walliser), *Oulodus* n. sp. A Over and Chatterton *Pseudooneotodus beckmanni* (Bischoff and Sannemann), *Ps. tricornis* Drygant and *Pterospathodus eopennatus* Männik. The apparatuses of some of these species can be reconstructed. *Pt. eopennatus* is the index species of the *Pt. eopennatus* Zone of the lower Telychian (early Late Llandovery). *D. staurognathoides* occurs from the Aeronian to the lower part of Telychian. From personal communication with Dr. P. Männik, Tallinn, a form that we had originally determined as *Oulodus* sp. is *Oulodus* n.sp. A Over and Chatterton. This corroborates an age of *Pt. eopennatus* Zone. Thus, the middle Sapandere Formation at its type locality can be assigned to the early Telycian (late Llandovery, Early Silurian).

DISCUSSION AND CONCLUSIONS

Dated Llandovery is rare in the Tauride-Anatolide Composite Terrane; conodont data were previously unpublished. In the eastern Taurides, conodonts of the *P. amorphognathoides* Zone of latest Llandovery to earliest Wenlock were found in the Yukanyayla Formation (Göncüoglu and Kozur, in press). The conodont fauna from Kemer is therefore the oldest known Silurian conodont fauna from the southern Taurides.

The conodont fauna from the middle Sapandere Formation allows an age diagnosis of considerable precision for this part of the Formation; early late Llandovery (early Telychian) *P. eopennatus* Zone. The conodont data are in agreement with Marcoux (in Dean and Monod 1990), who considered the nautiloid-bearing sandstones below the conodont sample as Telychian in age. The Silurian transgression began in the Antalya nappes somewhat prior to the Telychian, between Ashgill and middle Llandovery. This corresponds to the general transgression on the southern part of the Tauride-Anatolide Composite Terrane (Göncüoglu 1997) and in SE Anatolia, mostly over Late Cambrian to Arenig Seydişehir shales or facial equivalents. Siliciclastic Ashgill beds are sometimes also present (Şort Tepe Formation; Marcoux 1983).

Post-Tremadoc Ordovician fossils have a distinct Perigondwana cold-water association. When preserved glacio-marine deposits with exotic dropstones (e.g. orthogneisses and micaschists) are present in the Ashgill to early Aeronian interval. The late Llandovery (Telychian) conodont fauna, however, is a warm-water fauna.

The widespread dolomites in the lower Sapandere Formation are of probable middle Llandovery age. At Ovacik at the Mediterranean coast, they contain middle Llandovery graptolites (Dean *et al.* 1991). These are the oldest dated Silurian rocks of the southern Taurides.

Glacio-marine deposits with exotic dropstones are also reported from the Ovacik (Egripinar Formation; southern Central Taurides) and Tufanbeyli (Halityayla Formation, Eastern Taurides) areas within the lowermost part of the transgressive Silurian series. Acritarch data from the upper part of Halityayta Formation indicate a post-Rhuddanian to ?early Aeronian age (Dean and Monod 1990).

In the Middle East, transgressive clastic rocks overlying glacial sediments are known from central Sadie Arabia (Sarah Formation, Mahmoud *et al.* 1992) stratigraphically corresponding with the lowermost clastics of the Sapandere Formation or to the Halityayla Formation and the Egripinar Formation in the eastern and central Taurides, respectively. The black shales conformably overlying the clastics (Qusaiba Member of the Qualibah Formation; McGillvray and Husseini 1992) are diachronous. In the subsurface of the Riyadh area, its age is early Rhuddanian, whereas further to the northwest (Qasim area), outcropping early Aeronian graptolites have been found. The graptolite-bearing black shales in the Taurides correlate well with this unit. As with the Taurides, the black shales in Saudi Arabia are followed by an upward-coarsening late Llandovery sequence, the lower part rich in nautiloids corresponding to the "Orthoceras Limestone" in the upper part of the Sapandere Formation. This regional shallowing at the end of Llandovery is also recorded in Jordan (Berry and Boucot 1972).

The warming event after the Ashgill to lowermost Aeronian glacio-marine sediments were deposited was obviously very fast. The middle Llandovery transgression on the Tauride-Anatolide Composite Terrane, as documented in the Kemer area, Western Taurides was possibly connected with this (eustatic sea-level rise). The late Llandovery in southern Turkey, however, is represented by a shallowing upwards sequence, similar to the Middle East. This late Telychian regression seems to be a major event at the northwest Gondwana margin (Loydell 1998).

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